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The response shown to the announcement of publication of The Engineering Economist has been gratifying. As a result of a notice in Mechanical Engineering we have already received a number of subscriptions. There is the interest in this area which this publication anticipated.

The Engineering Economist intends to depart somewhat from the usual practice by presenting reviews and critical comments on currently published articles and papers, in addition to book reviews. This is done in view of the often substantial lead time in the presentation of advanced thinking in the form of articles and papers over that of books.

The next issue of The Engineering Economist will include a bibliography of current publications in this field.

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ECONOMICS OF ALTERNATIVE HIGHWAY PROGRAMS

by J.P.Buckley, Chief Engineer,

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Everyone who uses the highways is aware that automotive travel is becoming more difficult, time consuming and costly. The highway problem is becoming more serious daily because of continued increase in motor vehicle registration and total vehicle miles of travel.

Public awareness of the highway needs has been growing since the end of World War II. The scope of the needs and the necessity for drastic action has been brought into sharp focus recently by the report of the President's Advisory Committee on a National Highway Program, titled, "A Ten-Year National Highway Program", and by the report of the Bureau of Public Roads, "Needs of the Highway Systems, 1955-84".

Those two documents contain a tremendous amount of data covering all aspects of the highway situation today and in the future. I will discuss briefly some of the basic facts to properly position the subject matter of this talk -- "The Economics of Alternative Highway Programs".

There are now more than 58 million motor vehicles registered in the United States -- one for every 300 feet of highways. These vehicles travelad about 550 billion vehicle miles in 1954.

Both registration and travel are expected to continue upward. Conservative estimates expect 81 million vehicles by 1965, an increase of 40 percent, and over 800 billion vehicle miles of travel.

Vehicle registration and travel, however, are not the solo indication of the highway crisis. In addition there are increased sizes and weights of vehicles, higher average speeds, and a continued economic loss due to congestion, delays and accidents.

The shrinkage in the purchasing power of the dollar also has contributed to the problem. In terms of actual construction purchased, the level of highway con-

struction today is not much higher than it was in 1940, although travel has almost doubled.

The Bureau of Public Roads, after a state-by-state survey reports that total construction needs on all highways, roads, and streets in the next 10 years amounts to $101 billion dollars.

Since an estimated $47 billion dollars will be available for construction in the next 10 years under present finance plans, this means the construction rate must be more than doubled if needs are to be met.

This poses not only serious physical problems relating to materials, equipment, and manpower but also very important financial decisions.

In his highway message to the Congress, the President has proposed stepping up Federal aid to highways from $875 million a year to $3,120,000,000 per year. Principal features of the President's proposal are:

(1) Concentrate the additional Federal funds on the Interstate Highway System with a view to completion of the System in 10 years. The Federal Government would pay 92½ percent of the cost.

(2) Finance this program through a Federal highway corporation empowered to issue bonds backed by earmarking Federal gasoline and lubricating oil taxes.

Both the House of Representatives and the Senate have held long hearings on this and other highway proposals. The Senate has already passed a highway bill which differs materially from the President's proposal, but does provide a substantial increase in Federal aid.

Several important points of conflict have developed through the hearings, the major ones being:

(1) Pay-as-you go vs. bonding

(2) Term of program - 10 years, 15 years, or longer

(3) Emphasis on the Interstate Highway System or increased Federal aid for all systems.

It is significant to note there has been no controversy over the scope of the needs -- all admit their size.

The states are also facing the same problem: whether to finance their highways needs quickly with bonds or slowly on a pay-as-you-go basis.

Dollar needs are so tremendous that the alternatives are usually a pay-as-you-go program spread over a long period of years, usually 15 to 20, or a concentrated bond program spread over five to 10 years and paid in 20 to 30 years.

The pay-as-you-go program has the apparent advantage of being cheaper since there are no large carrying charges. On the other hand the user must wait 15 to 20 years for roads needed today and must continue to pay the huge economic losses of inadequate roads during this period - losses due to congestion, delays and accidents.

The bonding program has the advantage of providing needed roads in a more reasonable period of time resulting in large economic savings to the user as well as better service to the economy. The apparent disadvantage is the large expenditure for interest.

The big question before the Federal Government, the state legislatures, and many counties and cities then is - what are the economic aspects of the two basic alternatives and which alternative is the cheaper in the long run. The purpose of this paper is to report on some basic research on these economic aspects and the indicated conclusions.

Since the war some 30 states have conducted highway needs studies of all their roads and streets. The Foundation has worked with 19 states on such studies.

The studies generally followed a basic pattern. All roads were appraised to determine their physical condition and their ability to meet a set of minimum standards. Cost estimates were derived for the improvement of roads considered deficient.

The total of such costs were considered the backlog of needs. Since the backlog was usually very large, and must be spread over a period of years, other items had to be computed to arrive at the average annual cost of a highway program over

such a period of years. These other costs included:

Stop-gap improvements
Future replacement of roads now adequate
Maintenance
Administration.

Alternative annual programs were prepared by spreading the cost of the backlog needs over 10, 15 and 20-year periods and adding in the appropriate amounts for stopgaps, replacements, future capacity needs, maintenance and administration .

This table taken from a study published in 1950, "An Engineering Study of Ohio's Highways, Roads and Streets" illustrates such alternative programs for the 13,500 miles of major rural and urban state highways.

Table 1

AVERAGE ANNUAL COST
(In thousands of dollars)

	10 year Program	15 year Program	20 year Program
Backlog of Needs	$115,723	$ 78,149	$ 57,862
Replacement and Stopgaps	22,247	27,221	30,896
Future Added Capacity	13,990	12,393	9,382
Maintenance and Administration	31,896	29,783	28,665
Average Annual Cost	$183,856	$147,546	$126,805

The average annual cost decreases, of course, as the program period is lengthened, since the backlog is spread over more years. However, the costs of stopgaps increase because temporary work is necessary to hold roads in service until more permanent improvement can be accomplished.

The Ohio Highway Study Committee decided that on a pay-as-you-go basis, only the 20-year program was feasible. However, recognizing that 20 years was too long to wait, the Committee asked their fiscal adviser, Bertram H. Lindman, to investigate bond issue possibilities.

Lindman in his report "Supplemental Bond Financing for Acceleration of the Ohio Highway Program" proposed a $606,750,000 bond issue. This amount combined with normal revenues would overcome the backlog of needs in a 10 year period. The bonds were to be 10 to 20 year, two percent faith and credit bonds issued over the 10-

year period. Lindman's most potent argument for the bond issue is illustrated in this table.

Table 2.

OHIO BOND ISSUE COMPARED TO PAY-AS-YOU-GO

Total Cost of 10-year Program	$1,838,560,000
Replacements, Maintenance, etc.(Second 10-years)	619,080,000
Interest over 20-year Period	60,670,000
Total Cost 20-year Bond Program	$2,518,310,000
Total Cost 20-year Pay-As-You-Go	2,536,100,000
Apparent Savings	$ 17,790,000

The difference in cost of the 10-year catch-up program through bonds and the 20-year pay-as-you-go program was computed to be $78 million - the savings resulting from elimination of stopgaps and other deferral charges. Even after paying interest there was an apparent surplus of $18 million.

Most important, of course, is the fact that the economic and safety benefits of modern highways would be available 10 years sooner.

It is of interest to note that Ohio passed a constitutional amendment for a $500 million bond issue in 1953.

Many who have been involved in highway needs studies have been conscious that there were some weaknesses in methods of program development and presentation. Since replacements and stopgap improvements were computed statistically, and were based on past road life and construction experience under conditions of insufficient revenues, the costs tend to be low. Also, it was not possible to make proper allowances for other costs incurred due to long deferral of needed work such as increased traffic, additional costs of stage construction, dividing projects, etc.

Further, the methods of program presentation tended to indicate that the longer periods had financial advantage over the shorter periods except in such cases as Ohio, where other alternatives were explored.

To meet these weaknesses, new techniques were developed in a current highway needs study the Foundation is conducting in Tennessee in cooperation with the Tennessee Department of Highways. These techniques were developed and the research

carried on by C.F.McCormack, Deputy Chief Engineer and Harold Hansen, Special Assignment Engineer of the Automotive Safety Foundation in cooperation with Fred B. Farrell of the Highway Cost Section, Bureau of Public Roads.

The new techniques were first applied to the 944 miles or rural state highways in 10 counties representing the average of all conditions in the state. All of this mileage was carefully analyzed in the field to determine adequacy for a 20-year period and necessary improvements were determined and costs estimated.

Previous research by Farrell had established that over a period of about 30 years there are only slight variations between the total 30-year costs of alternative programs utilizing 10,15, and 20 years to overcome a backlog of needed improvements with current status maintained from then on.

It was decided, therefore, to extend the 20-year appraisal to 30 years by a detailed inspection of each section of the 944 miles and a determination of needed work in the 20 to 30-year period.

Replacements and stopgaps were determined individually for each section for each of the alternative program periods.

Each project was given a priority rating and assigned to a specific year for construction for each of the alternative catch-up programs, based on the available revenue for each year under the various programs. As projects were pushed into the future in the longer programs, stopgaps of course increased.

The initial program tabulation shown in this table confirmed, through specific analysis, the conclusion reached by Farrell statistically -- that total costs over a 30 year period are approximately the same whether the backlog of needs is met in 10 years, 15 years, or delayed 20 years.

Note that as the program period is extended the stopgap costs increase. However, this is compensated for by a reduction in replacement costs in the 30-year period due to the reduction in the amounts of new construction in the first 10 years.

Table 3

SUMMARY OF 30-YEAR COSTS
10 Tennessee Counties

	10-year Catch-up Program	15-year Catch-up Program	20-year Catch-up Program
Backlog of Needs	$99,200,000	$ 99,200,000	$ 99,200,000
Stop-Gaps	5,200,000	8,500,000	12,800,000
Replacements	28,900,000	25,400,000	20,400,000
Maintenance	43,500,000	43,300,000	43,100,000
Administration	10,600,000	10,600,000	10,500,000
Total 30-Year Costs	$187,400,000	$187,000,000	$186,000,000

Since a 10-year catch-up program would require more than tripling present expenditures in the 10 sample counties and even a 20-year catch-up would require almost doubling them, McCormack and Hansen investigated the possibilities of deficit or bond financing. The results of numerous complex cacluations are summarized in the next two tables.

Table 4.

SUMMARY OF 30-YEAR BOND FINANCING
(In millions of dollars)

ITEM	10-year Catch-up Amt	%	15-year Catch-up Amt	%	20-year Catch-up Amt	%
Capital Improvements	128.1	60.8	124.6	60.6	119.6	60.1
Stop Gaps	5.2	2.4	8.5	4.1	12.8	6.5
Maint & Adminis.	54.1	25.7	53.9	26.2	53.6	26.9
Interest @ 2%	23.5	11.1	18.7	9.1	12.6	6.4
Total	210.9	100.0	205.7	100.0	198.6	100.0
Av. Annual 30 year Cost	7.03		6.86		6.62	

This table shows that having modern roads in 10 years instead of 20 years would cost an additional $12,300,000 or 6.2%. That assumes bonding in both cases. If a 10-year bonding program is compared with a 20-year pay-as-you-go program, the difference is $24,900,000 or 13.4%.

While we have not found it possible as yet to precisely define the economic benefits of modern highways available data indicates that the saving in time, operating costs, and accidents would be far greater than the interest charge.

An example is a recent study by Ralph A. Moyer of the Institute of Transportation and Traffic Engineering of the University of California entitled "An Analysis of Highway User Benefits on the California Interstate Highway System Resulting from Completion of a 10-year Full Freeway Program".

Moyer's conservative analysis showed that the economic savings from completing the California Interstate Highway System in 10 years under a 30-year bonding program would exceed the entire capital cost plus interest. The total economic benefits over a 20-year period were computed at $3,850,000,000 while the total capital cost plus interest for 30 years was computed at $3,450,000,000 or $400,000,000 less.

It is recognized that the economic sa vings on full freeways are greater than on conventional roads and it is not contended that this California example would be true for a program covering all types of roads and streets.

However, many studies have shown that inadequate roads do cause large economic losses. The Automobile Manufacturers Association estimates that unsafe and inadequate highways cost the nation's drivers at least $5,300,000,000 a year -- or about a cent a vehicle mile. This is more than we are now spending annually for construction on all roads and streets. This includes the cost of extra gasoline, brake and tire wear in traffic congestion, needless accidents, and losses of time for commercial vehicles. Also included is increased auto insurance rates. There are also costs which defy precise measurement such as urban land blight and unrealized industrial and agricultural potentials.

The next table brings forth an even more fundamental economic point. That is, in such cases as Tennessee, where the current rate of expenditure is so far below the indicated requirements, a pay-as-you-go program in any reasonable period of years is probably not economically or politically feasible.

Table 5

COMPARISON OF PRESENT AND NEEDED REVENUES
(In millions of dollars)

ITEM	10-year Bonds[1]	Catch-up Pay-Go[2]	15-year Bonds[1]	Catch-up Pay-Go[2]	20-year Bonds[1]	Catch-up Pay-Go[2]
Total Costs	210.9	114.2	205.7	138.3	198.6	154.7
Pres.Expend.Projected	147.0	36.5	147.0	59.5	147.0	85.6
Deficit	63.9	77.7	58.7	78.8	51.6	69.1
Av. Annual Deficit	2.13	7.8	1.96	5.3	1.72	3.5
Percent of Pres. Exp. Projected	43%	211%	40%	134%	35%	82%

1. Thirty-year costs for bond program
2. Pay-as-you-go costs for catch-up period only.

For example, a 10-year pay-as-you-go program would require increasing the current level of expenditures and hence, taxes, by 211 percent as against a 43 percent increase over a 30-year period through bonding.

Even a 20-year pay-as-you-go program would require increasing current expenditures by 82 percent.

This is not necessarily true in all states. California, for example, has found it possible to make tremendous gains on a pay-as-you-go basis.

In summary, this Tennessee research shows: (1) The total cost, over a 30-year period to build a modern highway system on a pay-as-you-go basis, is essentially the same whether the backlog is met in 10,15, or 20 years. (2) The interest charges on a sound, 10-year bond financing program are more than off-set by the economic savings from having modern roads quicker. (3) Bond financing provides a realistic answer to highway modernization in states where the gap between current and required annual expenditure is excessive.

The Tennessee Highway Department and our staff feel that the findings of this sample analysis are so significant that the analysis is currently being extended to cover all principal state, county and city roads and streets. When this work is completed next fall, the Tennessee legislature will have before it detailed engineering and finance data showing costs and benefits of several alternative pay-as-you-go and bonding programs.

This will be the first time, to our knowledge, that an analysis of this type covering all major roads and streets has been placed before a state legislative body.

Obviously, the final decision as to the most practical alternative must be made by the legislative bodies and neither this paper nor the final Tennessee report are intended to promote or urge bond financing.

It is believed, however, that the wisest decisions in such a technical area can be made only when the technicians produce and define the economics of alternative programs.

RISK ANALYSIS IN ENGINEERING ECONOMY STUDIES

by
Fred A. Gitzendanner, Associate Director, Engineering Research Department, Standard Oil Company, Whiting, Indiana

(The full text of this paper appears in the October issue of The Journal of Engineering Education. Following is a brief outline of Mr. Gitzendanner's approach:)

Mr. Gitzendanner's paper deals with the large storage tanks found in refineries. The particular tank in this case was 120 feet in diameter and 50 feet high and would hold about 3,500,000 gallons. The refinery where it was located is situated in hilly country and the storage tank areas require horizontal terraces to be excavated in the hillsides to provide the necessary level spaces. It is customary in connection with such tanks to fill them with water in order to test for leaks before putting them into petroleum service. In this particular case, approximately ¼ of the foundation area under the tank settled excessively during the initial water test. The tank was not damaged by the settlement of the foundation but was unsafe for service in that condition and the foundation had to be repaired.

Technical study of the problem narrowed the practical corrective steps down to these three: (1) Grout under the tank for $30,000; (2) excavate and put in fill, $80,000; (3) relocate the tank, $160,000.

Among possible causes of failure of the tank were:

(1) a poorly compacted volume of soil of relatively limited extent which could be corrected by grouting;
(2) a shear failure of the soil under the tank;
(3) the possibility that the settled portion of the foundation was actually the beginning of a small landslide.

Relocating the tank at a cost of $160,000 would definitely solve the problem. Either of the two less costly methods might also prove successful.

An analysis requires:
1. List all possible courses of action.
2. Develop the economic inter-relationships
3. Synthesize the problem down to understandable proportions suitable to the problem at hand.

Mr. Gitzendanner calls attention to the fact that the problem is completely surrounded by uncertainty and that there is a possibility of taking a "calculated risk". Taking a "calculated risk" is a way of saying that probabilities are being analyzed and compared. Probabilities are analyzed for economic problems in the following way: "Consider only for a moment the $160,000 relocate and the $80,000 excavate and fill alternatives. A definitely satisfactory result could be obtained at a cost of $160,000. If the $80,000 excavate and fill alternative were tried and failed, the satisfactory correction would then cost that $80,000 plus $160,000 more to relocate the tank or a total of $240,000. Therefore, if the $80,000 first step alone were successful one-half the time, the average cost of all cases would be the same as using the $160,000 alternative. Stated differently, a 50-50 chance (50% probability) of success for the excavate and fill course is the break-even point. If the chances of the excavate and fill step succeeding were better than even, then that solution had the greatest probability of being the most economical selection.

The paper is devoted to analyzing these alternatives.

Comments on "Risk Analysis in Engineering Economy Studies" by:
LORING G. MITTEN, The Ohio State University

Engineers are frequently confronted with decision problems in which the desirability of a particular course of action is dependent on the value of one or more unknown parameters. Mr. Gitzendanner treats the class of such decision problems in which it is possible to reduce the number of uncertain variables to two dichotomous statements (for example: condition A either holds or does not hold; and condition B either holds or does not hold). All possible courses of action are listed, and the expected economic consequences of each alternative are stated as function of P(A)(the probability that condition A holds) and P(B). Thus, if alternatives 1,2,...,m are available, then the expected cost (or profit, etc.)functions $C_i = f_i[P(A),P(B)]$. are derived for i = 1, ..., m.

A "break-even" line is then plotted on the P(A) vs. P(B) plane for every possible pair of alternatives (i.e. the functions F_{ij} ,with $P(A) = F_{ij}[P(B)]$ if and only if $C_i=C_j$, are plotted for all i,j = 1, ..., m($i \neq j$). The P(A) vs. P(B) plane is thus divided into a set of regions, with one specific course of action definitely preferred (on the basis of expected cost, profit,etc.) at every interior point of a particular region. Expert opinion is consulted to determine which values of P(A) and P(B) are, in fact, expected to obtain. Using these values and the chart described above, the decision is reached.

Two interesting examples illustrate the method, one treating the choice of alternative production processes and the other dealing with a problem encountered in constructing a "tank farm". Left open are such theoretical questions as the validity of using "informed guesses" in an expected value equation and restrictions on the form of admissible utility functions.

Comments on "Risk Analysis in Engineering Economy Studies" by
NORMAN N. BARISH, New York University

Mr. F.A.Gitzendanner's paper is an excellent presentation of a very valuable approach which I hope can be developed into a technique with exceedingly wide possible application. It is the kind of approach which we should try to develop further and see if we cannot generalize the methodology.

Even though we cannot obtain or estimate the probabilities or risks of occurrence of the alternatives with any high degree of accuracy, this technique which Mr. Gitzendanner has developed enables us to concentrate the judgemental processes and decisions into a few critical areas at the very end of the calculations. In this manner, those charged with the responsibilities for making the capital investment decisions in the company have a sounder basis for making these decisions: by evaluating the probability or risks in familiar, easily understood terminology. This is preferable to having the critical risk evaluation made by analysts down the line in the organization when they are preparing the cost estimates in connection with the capital investment proposal. In many cases, engineering knowledge of the situation will reveal an order of magnitude for the probabilities which will suffice to clearly indicate to management which of the alternative investments is the best.

One question occurs to me: would we not have come to the same conclusion in the case presented by Mr. Gitzendanner by using the conventional approach of computing expected costs for each of the alternative courses of action? In this case, it certainly appears that we would have arrived at the same conclusion using the conventional approach assuming that the analyst gave the same values to the probabilities. However, the values for the probabilities would have been buried in the calculations of the alternative costs and would not be readily discernable to the person making the capital investment decisions. The top management person making the investment may thus not even evaluate the reasonableness of the probabilities assumed by the analyst. In Mr. Gitzendanner's approach, the risks are considered variable until the final solution of the problem. Management therefore evaluates these risks in making the final decision. Management is therefore more clearly aware of these risks and what effect they may have on the relative economy of the alternatives being considered.

This paper has emphasized an area which the standard texts have tended to neglect. The difficulty of applying the conventional solutions is that the most that we can frequently hope to do in problems involving risks is to establish an order of magnitude for the probabilities. In some cases, as in Mr. Gitzendanner's problem, this will provide enough information to solve the problem. In other cases, we just cannot solve the problem quantitatively because the relative cost advantages are very close together. Mr. Gitzendanner's approach can pinpoint this type of situation. We should study his approach carefully to see what other possible applications can be made.

It is very interesting and unusual to have industrial people formulating their economy problems in this manner. It would benefit the science greatly if more people in industry were thinking along the lines of Mr. Gitzendanner's presentation. As teachers of engineering economy, we are greatly indebted to Mr. Gitzendanner for giving us this practical case history of an unusual solution to a perplexing type of economy problem. We need more cases like this from industry.